Thermocouple Extension-Wire-Connections and Low Temperatures

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ABSTRACT

Experiments were carried out at the NASA Stennis Test Technology Laboratory to determine the cause of erroneous readings from thermocouples of type K when measuring temperatures of liquid hydrogen (LH_2). This behavior was believed to be linked to the temperature of the connector used to extend the thermocouple wires to the voltage meter. The connector could sometimes become surrounded by ice formed around LH_2 pipes thus remaining at a temperature significantly lower than ambient. The tests confirmed that, indeed, when the thermocouple is measuring liquid nitrogen (LN_2) and the connector is also immersed in LN_2, an error of approximately 8°F occurs. The culprit for this error, however, is not strictly the connector, but rather the wires on each side of the connector. Further, in order to simulate conditions at the test stands, the connector was immersed in temperatures ranging from 32.2 °F to 208.3 °F. For this range of connector temperatures, the maximum error recorded was around 1°F.

BACKGROUND

Thermocouple performance is well documented for a wide range of temperatures [1-3], but little documentation is available for cryogenic applications. For the problem at hand, One could think of the connectors as additional thermocouple joints. *Assuming that the wires on both ends of a connector are of the same exact thermocouple material*, the following system is defined (Figure 1). A junction "wire-connector element" is formed at one screw terminal, followed by a junction "connector element-connector element" (male and female ends of the connector), followed by a junction "connector element-wire." If the connector elements on the male and female sides are of the same exact material (same production batch), then the voltage generated at these junctions cancel each other as long as they are kept at the same temperature. It is reasonable to make this assumption, but if unsure, confirming tests must be performed.

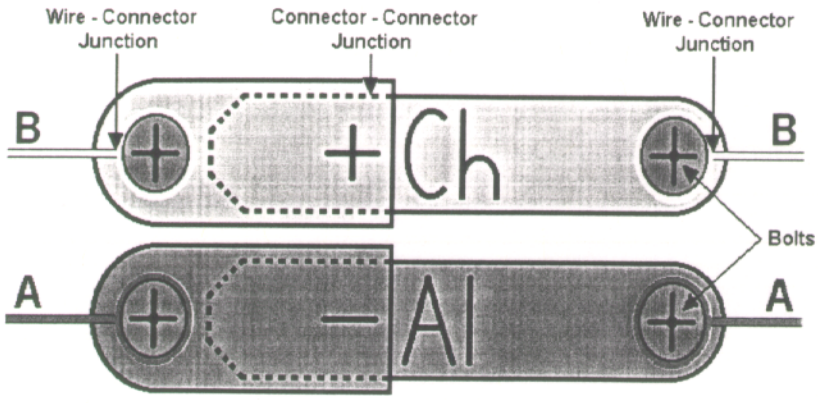

Figure 1. Detail inside a thermocouple Type K connector

Given the connector system described above, it is reasonable to think that *an error in temperature readings will occur when the thermocouple wires on each side of the connector are not exactly the same (not of the same batch - for practical purposes).* In this case, the "wire-connector element" junction on the left side produces a voltage different from the "connector element-wire" junction on the right side. At low temperatures, this difference is enhanced because the junction's sensitivity increases (dT/dV is larger).

EXPERIMENTAL SETUP AND PROCEDURE

The experimental setup is shown in Figure 2. The thermocouple T is connected directly into a standard connector, C_1. A second connection at C_2, was used to extend the wires further. Wires on either side of C_2 were not of the same production batch. An ice bath was used as reference and the voltmeter probes were kept at room temperature. The connection at C_2 was tested first using a standard thermocouple connector and immersing it in temperatures ranging from –319 °F (LN_2) to 208.3 °F. Other tests were done without a connector, where the connection was made by twisting the wires and also by welding them.

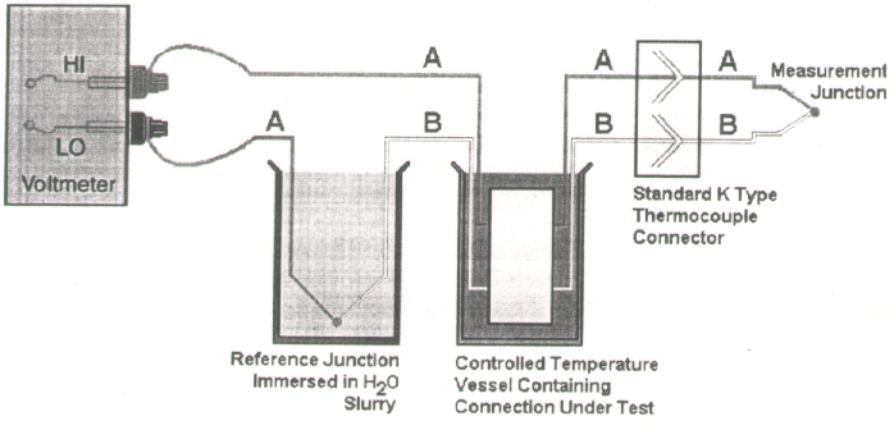

Figure 2. Experimental setup

RESULTS

A voltage change of approximately 0.060mV (7.5°F) occurred when the connector was immersed in LN_2 (from ambient temperature). When the connector was heated, only small changes were observed with a maximum of 0.012 mV (1°F). When the uncut wire was immersed in LN_2 (simulating a perfect connection with exactly the same material wire on both sides) no changes in voltage were observed. A change of 0.077 mV (8.5°F) occurred when the twisted wire replacing the connector was immersed in LN_2 (signaling that the connector itself was not causing the errors). To insure that wires being connected were exactly the same (came from the same production batch), the piece of wire between the connectors was cut and a new twisted wire connection was made. Immersing this connection in LN_2 changed the voltage only minimally (equivalent to less than 1°F). When a connector was used to reconnect the cut wire, again, immersing the connector in LN_2 changed the voltage only minimally.

The experiments made it clear that using thermocouple wire from different batches on opposite sides of a connector causes errors. The magnitude of the errors is increased when the connection is immersed in low temperatures. The reason for this is because the junction behavior must be such that its sensitivity increases at lower temperatures (dV/dT is large, as in K-type junctions).

RECOMMENDATIONS

1. When using thermocouples with a connector attached next to the sensor, the connector must be kept at ambient temperature. Ice must not accumulate around this connector. The reason is because the extension wire used on one side of the connector will most likely not be of the same batch as the wire going to the junction. It is best to use a thermocouple with a long wire to avoid a connector close to the sensor.
2. Regardless of the local temperature at the connector, as long as the wires on each side of a connector are of the same batch (spool), the measurement error will be within the specifications of the thermocouple.
3. When a connector is subjected to ambient temperatures that change from freezing to 208.3°F, the error will be minimal (on the order of 1-2°F). According to the tests performed, this is true even if wires from different batches are used across connectors. However, if thermocouple wires from different production batches are more dissimilar, larger errors may occur.
4. Best practice when utilizing connectors is to use wire of the same batch to extend the wires of any thermocouple.

REFERENCES

[1] Richard S. Figliola and Donald E. Beasley, Theory and Design for Mechanical Measurements, John Wiley & Sons, Second Edition, 1995.

[2] National Institute of Standards and Technology, www.nist.gov, accessed on 9/20/2000.

[3] Omega Corporation Temperature Measurement Catalog, www.omega.com, accessed on 9/18/2000.

[4] Figueroa, Fernando; Mitchell, Mark; and Richardson, Gregory, "Thermocouple Errors Associated with Extension-Wire-Connector Temperatures," NASA/TM-2000-210579.

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